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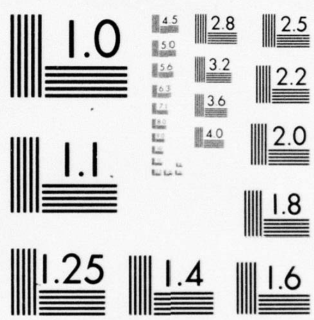

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STUDY PROJECT

3 JUNE 1977

MANAGEMENT OF RESEARCH AND DEVELOPMENT FOR ELECTRONIC SYSTEMS

BY

MR. GEORGE L. WOOLEY
NATIONAL SECURITY AGENCY

US ARMY WAR COLLEGE, CARLISLE BARRACKS, PA 17013

USAWC MILITARY STUDIES PROGRAM PAPER

MANAGEMENT OF RESEARCH AND DEVELOPMENT FOR ELECTRONIC SYSTEMS

INDIVIDUAL STUDY PROJECT

by

Mr. George L. Wooley

US Army War College
Carlisle Barracks, Pennsylvania 17013

3 June 1977

ABSTRACT

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The intent of this investigative research effort was to perform a critical appraisal of the Department of Defense technological innovation process in the light of recent research in private industry technological innovation. The study focuses specifically on Research and Development and technological innovations for electronic systems. The focus is directed toward electronic systems because of the thesis that electronic technology is progressing rapidly enough to make the life span of technologies less than the optimum DOD system acquisition cycle time. The study concludes that more DOD electronic systems will be fielded with obsolete computer subsystems unless changes are made in the military R&D approaches. The first recommendation is that Department of Defense establish a program of joint service evaluation of competing technologies as part of electronic systems development projects. The study also recommends the establishing of a more meaningful incentive program for government and contractor personnel that is unique to technological innovation. Based on the author's experience, personal interviews and literature searches, the study offers a model of the DOD technological innovation process and a qualitative profile of DOD R&D in totality.

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CHAPTER I

INTRODUCTION

> There is widespread confusion and misunderstanding about the research and development process, and about what it can and cannot do.
>
> Honorable William P. Clements, Jr., 1976

Managing Research and Development is difficult and challenging for most organizations whether government or private industry. This difficulty is no excuse for not managing R&D as efficiently and effectively as our management knowledge will permit.

In managing effectively we can maximize our revolutionary and evolutionary technological innovation in the face of the military needs and what Possony and Pournelle's book The Strategy of Technology Winning the Decisive War calls "technological warfare." If we are efficient in managing R&D, we can minimize disfunctionalization and risks. One area where management knowledge has increased significantly is our knowledge and information on the technological innovation process (to be defined later).

> While we cannot ensure success, there is ample scope for improving our ability to avoid failure.
>
> Bran Twiss, University of Bradford Management Center, Great Britain

This increased research and knowledge of the technological innovation process occurs at a time when many have become critical of the cost, schedule, and performance record of DOD R&D management. It is therefore ironic that this performance record continues at a time when the purpose of recent research in the innovation process

is to provide data for improved R&D management through a better understanding of the variables in the innovation process.

Goal

This paper focuses on the idea that some of the recent research and insights into the technological innovation process and R&D management must yield information for improved DOD R&D management, particularly in the area of electronic systems which this paper will explore. The goal for this study can be subdivided as follows:

1. To perform a critical appraisal of the DOD technological innovation in the light of recent research in private technological innovation.

2. To investigate the factors that promote technological innovation in Defense Electronic Systems.

3. To exploit recent research on technological innovations for benefits to DOD R&D managers and specifically electronic systems R&D managers.

4. To identify and analyze implementing vehicles for improved R&D management factors for Electronic Systems.

Thesis

This paper is based on the thesis that we can and must manage electronic systems R&D in a fashion that will maximize revolutionary and evolutionary technological innovations while minimizing disfunctionalization and risks. This conviction springs from the following observations:

1. Electronic technology is progressing rapidly enough to make the life span of technologies less than the optimum DOD system acquisition cycle time.

2. An increased amount of research into private industry technological innovation is available to be exploited for DOD.

3. The cost, schedule, and performance difficulties of DOD Electronic Systems Research and Development are sufficient to warrant study in the context of managing innovation.

Boundaries of this Study

Definitions

Technological innovation is defined as the introduction and successful passage of unique ideas, new design concepts, and new technology through the research, exploratory development, advance development and engineering development phases of R&D programs. This definition is closely related to the Battelle Study definition for the industrial environment which states:

> A complex series of activities beginning at first conception when the original idea is conceived; proceeding through a succession of interwoven steps of research, development, engineering, design, market analysis, management decision making, etc; and ending at first realization; when an industrially successful product, which may actually be a thing, a technique, or a process, is accepted in the marketplace.[1]

Delimiters

Two delimiters will be at work during this study. They are: (1) technological innovation as part of the DOD R&D process will limit the scope in subject, and (2) the applicability of technological

innovation to DOD electronic systems will limit the scope in the practical context.

This study will focus on how we manage technological innovations as part of DOD R&D programs. Please note in Figure 1 that DOD technological innovation is a subset of technological innovation for the scientific community including private enterprise. Electronic system innovation is a subset of DOD technological innovation. Electronic system innovation includes a subset called electronic component innovation. The intent of this study is to do an appraisal of DOD technological innovation while investigation approaches to managing innovation for electronic systems.

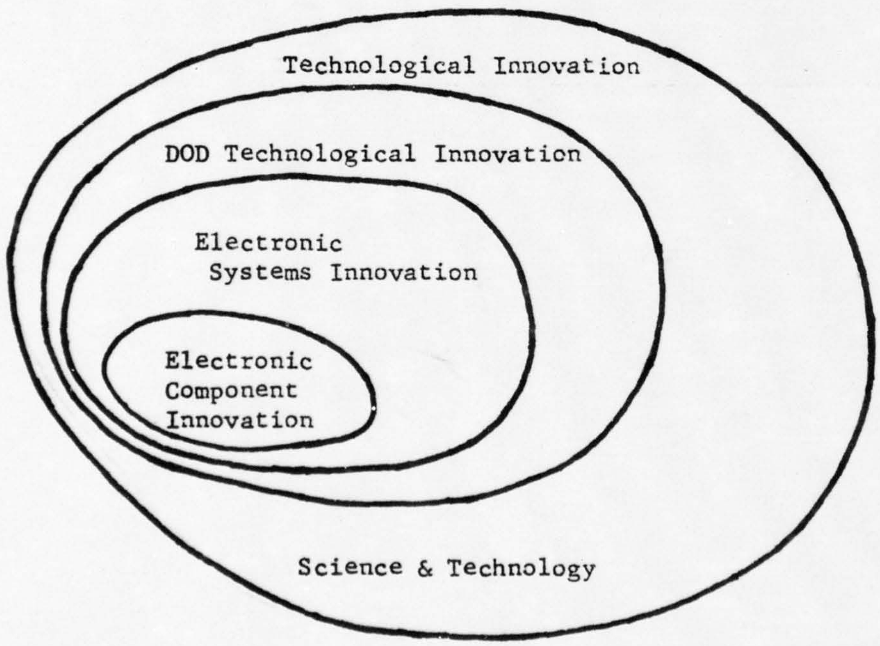


Figure 1

Technological Innovation--Set and Subsets

The need for investigation of innovation in electronic systems has never been more paramount. Consider one view of the rate of innovations in the industry from which we draw DOD electronic technology. The 14 April 1977 issue of the McGraw Hill publication ELECTRONICS introduced the new products for two weeks of technological progress. The ELECTRONICS innovations for two weeks included the following: 11 new computer subsystems (display terminals, microprocessors, etc.), 11 new components (memory devices, interface parts, etc.), and 6 new instruments. Since this new products article only covers a small percentage of the weekly electronic innovation potential, one should visualize the thousands of new computer subsystems offered each year.

DOD system designers for electronic systems are encouraged to use off-the-shelf subsystems and even total systems where possible. No other area of DOD R&D is offered such a mass of potential off-the-shelf hardware from a technology that changes each week.

Granted, many of the innovations introduced each week such as computer subsystems are evolutionary technological innovations, but these new products offer improvements perceived to be sufficient to give the new products a competitive edge. We will investigate the technological forecast to see what revolutionary innovations are near.

Military electronic systems must be designed with this technology where the level of subsystem performance changes each week. The author takes the view that no other field of DOD R&D is more dynamic. Hence, electronic systems have been singled out for this

study with the hope that we may systematically address the problems of managing R&D in this dynamic environment.

Perspective--the Past

In the hearings on the Army's 1946 appropriations bill, some congressmen had expressed the fear that a lack of war pressure would be followed by a relaxation of R&D efforts and urged the DOD R&D program be maintained.[2] R&D continued strong as the decade of the 1950s approached and the Korean War prompted a sharp rise in the military expenditures for R&D. However, the demonstration by the USSR of its capability in the rocket/missile area by the Sputnik I launching in 1957 came as a severe shock. That event shattered any views that the United States held a monopoly on the frontiers of science and technology. DOD expenditures for R&D had a slow rise to $652 million in 1950, but the rate increased sharply to $7.672 billion in 1964.[3]

DOD scored high on innovations in the pre-1960 era because of a technology push in the areas of:

Rocket propulsion

Missiles

Radar, sonar, ECM

Atomic bombs (nuclear technology)

Electronic (solid state)

Computer technology.

However, this period of high innovation shared a compliment of troubles:

High risk program

Increased cost overruns

Lack of promised performance

Low effectiveness

Inefficient use of resources

The McNamara regime of 1961-68 instituted PPBS/FYDP, systems analysis, cost effectiveness and a new dimension in systems acquisition. Some have said the strong emphasis of this era to balance technical performance, cost, and schedule worked at the expense of innovation.

> RFP's to contractors were not only technical performance oriented but more often than not dictated a particular solution as to configuration rather than allowing industry to come up with other approaches or to innovate.[4]

The concept of total package procurement was put forth during this time frame as a way of dealing with weakness of previous ways of acquiring systems. DOD Directive 3200.9, issued on 26 February 1964 and reissued 1 July 1965, demonstrated a sensitivity to innovation process in establishing the Concept Formulation phase for major programs. The objective of the Concept Formulation phase was to provide technical, economic, and military conditions as a basis to initiate engineering development.

Technology offered both products and promises and DOD Directive 5000.1 dated 13 July 1971 appeared to put this message into the major systems acquisitions. The main areas of this directive were: (1) technology base including independent R&D, prototyping, and technological advances, (2) systems needs including operational limits,

existing technology products, and equivalent needs, and (3) program structure including pacing functions, relationship of need and risk, trade-offs, and cost parameters.

While R&D management has made moderate changes to deal with problems that have continued for 15-20 years, technology growth for electronic systems has accelerated at a phenomenal pace. From the macro point of view consider the history of computer technology from the second to the fourth generation machine. The computer instruction cycle time has been reduced by more than a factor of one hundred while memory available has been increased by a factor of thousands.

Still in the macro view, pocket calculator history spans less than five years and the price of a pocket scientific computer has been cut by a factor of ten to one in less than three years. While these changes have been perceived as merely more capability per dollar in the private sector, they have stimulated growth in concern for sophistication in the military sector.

While facing some of the same problems in R&D management for the past 15-20 years and having made our way into the future in the face of new problems, where do we go from here? The appraisal in the following chapters will help us address this question based on the thesis presented earlier.

"The future is here and it works."--Lincoln Steffens

CHAPTER I

FOOTNOTES

1. Battelle Columbus Laboratories, _Science, Technology and Innovation_, February 1973.

2. Clarence H. Danhof, _Government Contracting and Technological Change_, 1968, p. 41.

3. _Ibid._, p. 76.

4. Melvin B. Kline, "A Critical Appraisal of the Requirements Determination Process," Naval Aviation Executive Institute Colloquium, Naval Postgraduate School, April 1976.

CHAPTER II

THE PROCESS OF INNOVATION

Before going into the process of innovation, the question of what is technological innovation deserves more treatment. First, we distinguish innovation from invention in terms that successful satisfaction of a demand is not a prerequisite for invention but successful user satisfaction of a demand is a requirement for successful innovation. Secondly, innovation is distinguished from imitation. A useful distinction can be drawn between the words innovation and invention as follows:

Invention--to conceive the idea.

Innovation--to use the process of translating the idea into the hands of the users.

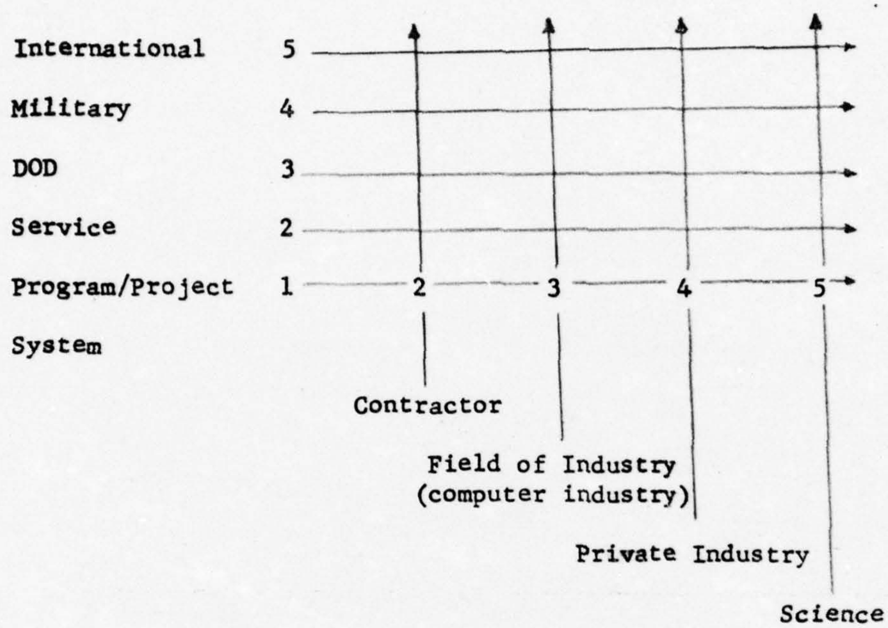
Since unbounded nonimitation offers a range of ambiguity, consider the matrix in Figure 2 as a tool in defining innovation in terms of information transfer. Here a 3/2 innovation is new to the branch of service and new to contractor but not new to DOD or his field of industry. Revolutionary innovations or breakthroughs are associated with the level above three on the matrix. Evolutionary innovations are associated with levels three and below for the purpose of this paper.

States in the Innovation Process

The classical view of the innovation process begins with recognition of the new idea. Myers and Marquis states as follows:

Figure 2

Level of Information Transfer Matrix



(NOTE: Technological innovations generally require technology transfer. This matrix allows us to quantify the domains that might participate in technology transfer.)

> Successful innovation begins with a new idea which involves the recognition of both technical feasibility and demand. At this point in time there exists a current state of the art, or inventory of technological knowledge, of which the innovator is more or less aware, and on which the estimate of technical feasibility is based.[1]

The term "demand" should be emphasized. In commercial R&D, a potential demand is often created through marketing when the demand for a new system does not exist. The idea of demand creation is more than a concept, of technology-push vs. requirement-pull. It involves advertising, promotion, and demonstration until a demand is generated. In studies of innovation stimulus data shows that most innovations (70%) are stimulated by market demand.

There is a clear distinction between market recognition in the commercial context and requirement determination in the DOD context. By directive, DOD requirement determination is intended for critical needs or "genuine requirements." Consumer markets cover a range of need levels. If these needs levels are distributed according to the normal distribution, they cover needs ranging from moderate desire to absolute necessities. For example, I have a <u>requirement</u> for daily transportation, but I have a <u>need</u> for two automobiles, one of which has air-conditioning, automatic transmission, AM/FM radio, and four-door sedan model.

The idea recognition stage of the innovation process is followed by idea generation.

> The idea for an innovation consists of the fusion of a recognized demand and a recognized technical feasibility into a design concept.[2]

Goldhar studied "Industrial Research 100" aware winners for the types of sources and channels of information in the idea generation stage. Table I shows the results of the study and it is of interest to note that, whereas 70% were need-stimulated, less than 25% were stimulated by what could be classed as a "requirement."[3] The idea generation stage of the innovation process is combined with the other stages in Figure 3.

TABLE I

Type of Information Reported Having Greatest Values as a Stimulus to Innovation

	% Reported as Greatest Value
General Market Need (E)	24
A Specific Client's Need (E)	12
A Different Innovation (T)	2
Generally Available Technical Data (T)	7
Specific New Technical Information (T)	14
A Production Requirement (T)	2
Your Firm's Need to Offer a Competitive Product (E)	1
A Need to Reduce Product's Selling Price (E)	0
A Need to Reduce Production Costs (E)	1
Firm's Need for a New Product (E)	4
Your Own Recognition of New Technical Possibility (T)	23
Your Own Recognition of a New Economic Opportunity (E)	7

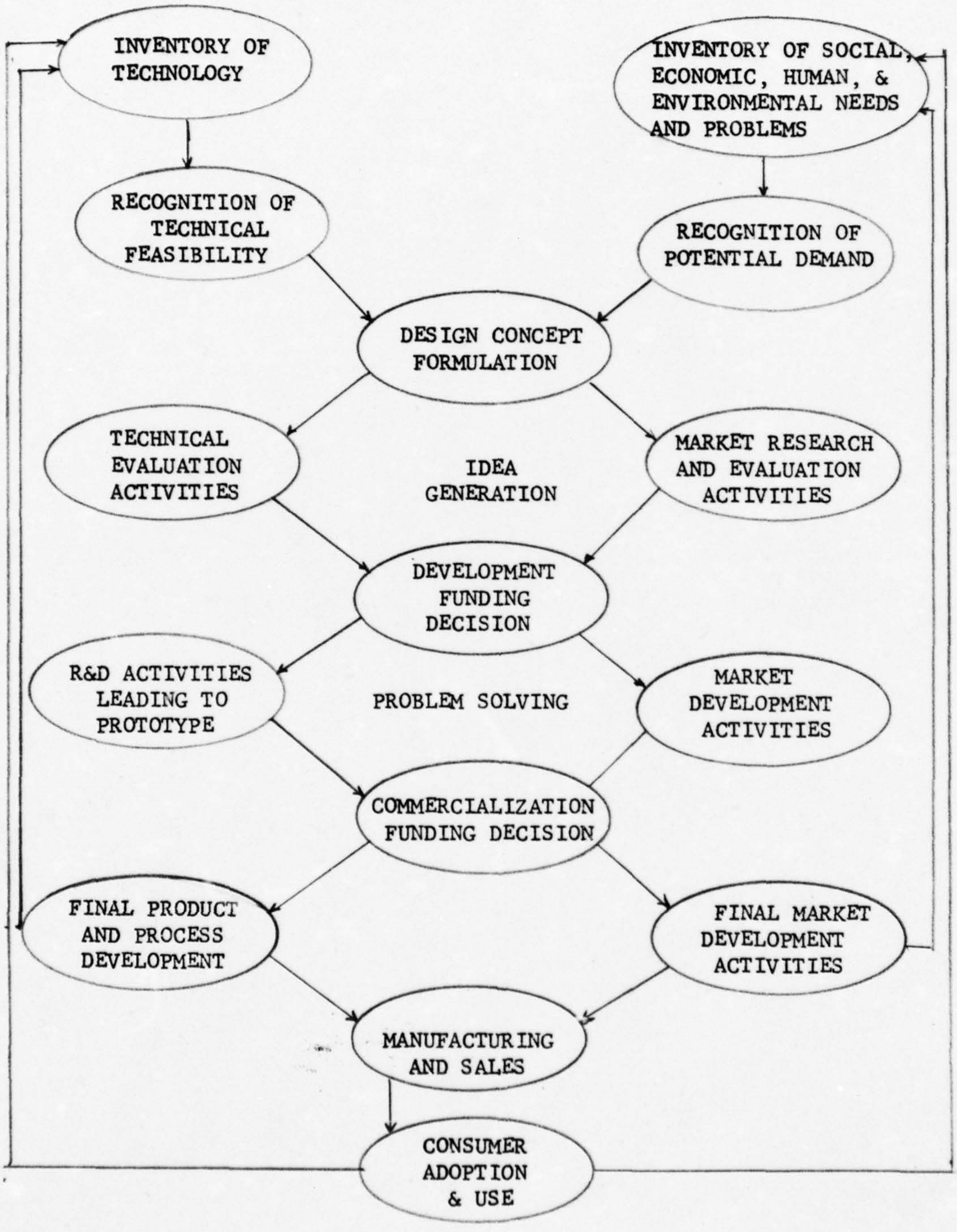
Note: E = economic information
T = technological information

DOD Technological Innovation Process Model

DOD technological innovation process as presented in Figure 5 was developed by the author from research conducted during this study. The DOD process differs from the private industry process in four areas. First, DOD embodies the requirements determination

Figure 3

The Process of Technological Innovation[4]



process as opposed to the market development process. The DOD need must be perceived as a requirement which demands a share of future procurement dollarsand the market development is based on a share of a competitive market of needs expected of the consumer. Arch McGill, former Vice President of Marketing for IBM Corps, defined managing as: "modifying people perception of the product or service you offer."

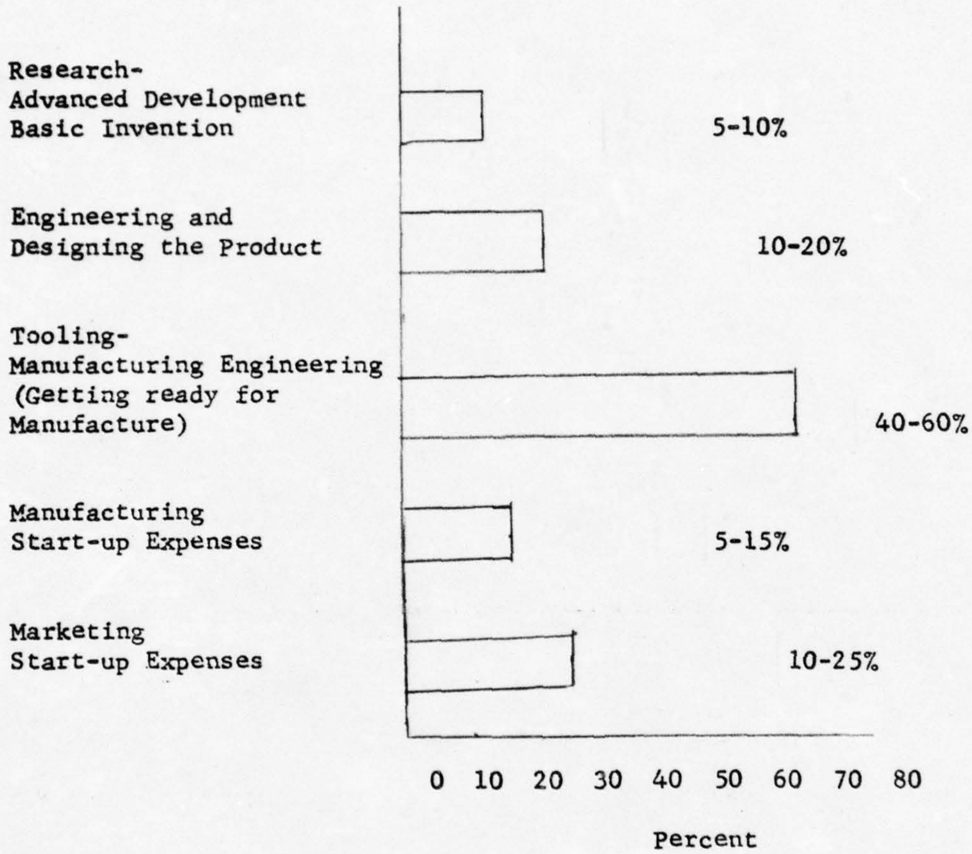
The idea of modifying people perception is not a significant part of the DOD requirement determination process.

The second difference of the DOD model is the sequential nature of the R&D and requirement evaluation decisions. Consider the distribution of costs in successful product innovations in Figure 4.[5] The marketing expenses of 10-25% generally exceed the engineering and design cost. When the DOD manager makes the decision to proceed with engineering, he makes that decision without an equal expenditure focused on modifying people perception of product. Therefore, the DOD requirement to determination decision is forced into a sequential decision with significant amount of analysis, studies, collaborations.

The third difference of the DOD innovation process from the commercial process is the transition from requirement to need. For example, the commander will have a <u>requirement</u> for a radio in his vehicle, but the commander may <u>need</u> a VHF and UHF radio. When this need is satisfied, we make the transition from requirement to need. Many human engineering type considerations will promote a transition from system requirements to human needs in the system.

Figure 4

Typical Distribution of Costs in
Successful Product Innovations



Whereas other differences may exist, the final DOD process model difference addressed in this study are the feedback loops in the DOD innovation process. Goldhar's study of innovation stimulus showed that 85% of the "Industrial Research 100" award winner when stimulated through informal channels.[6] This trend differs from the policy of DOD directives and DOD practice. Secondly, Myers and Marquis showed a great sensitivity of commercial R&D to the use of existing production processes. Feedback of the type depicted in Figure 3 facilitated innovations that required no significant changes in existing production processes in 50% of the cases studied.[7] In contrast, the DOD model shows greater sensitivity to the life cycle support of the innovation.

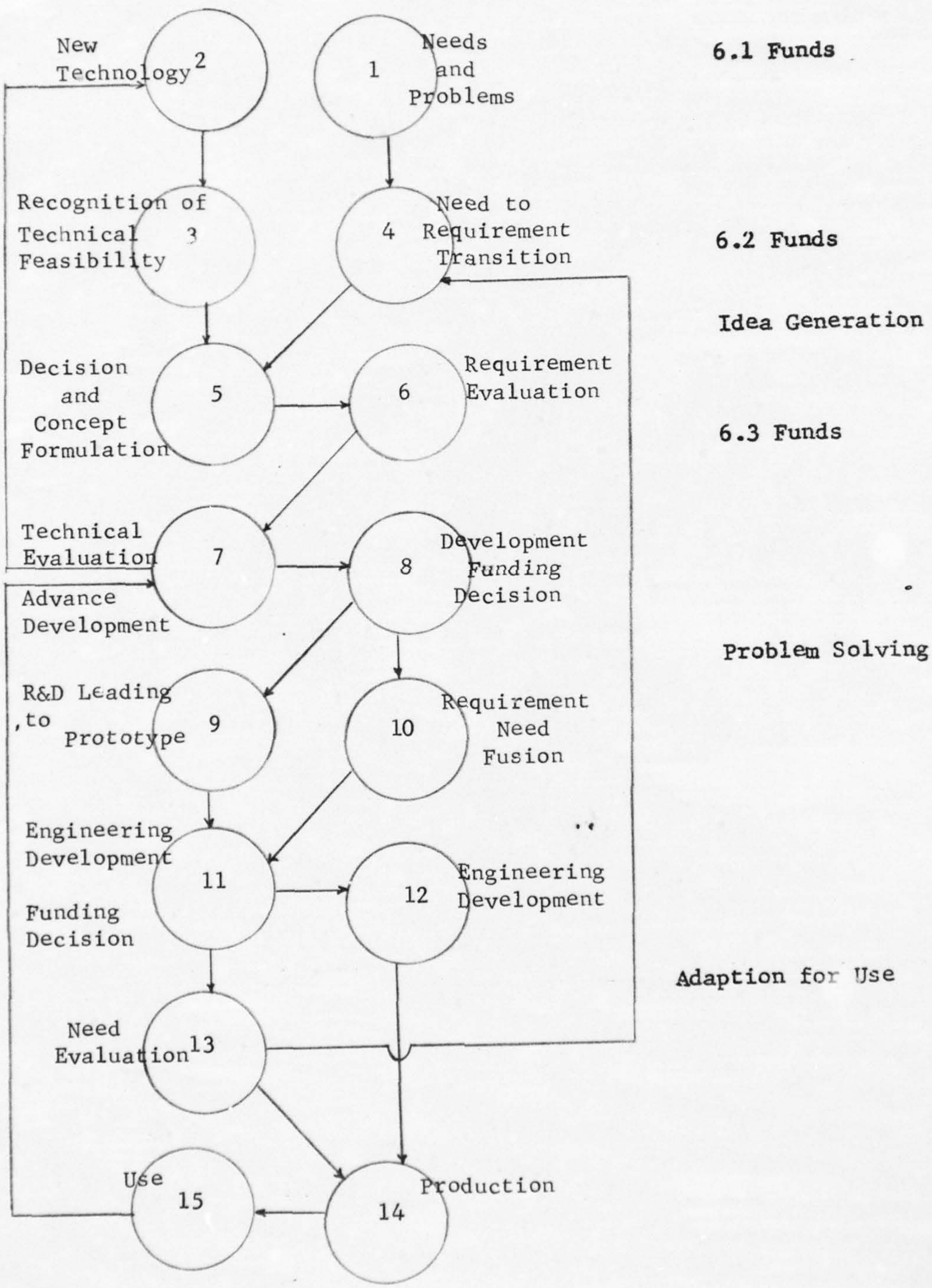
<u>DOD Process Observations--Summary of Interview</u>

A group of government and industry representatives were interviewed on several issues pertaining to DOD R&D management (see Appendix I). Each interviewee was asked to identify the major problems in the 6.1-6.3 (see Figure 5) portion of the DOD technological innovation process.

The major problem by far involved activity No. 3, recognition of technical feasibility in the DOD process model (Figure 5). The problem was viewed from a different perception depending on whether a professor, industry R&D manager, or government R&D manager. A clear majority emphasized a continuous DOD problem of loss of opportunities for innovation or loss of technological opportunities at a program stage described by activity 3 of Figure 5. Other

Figure 5

DOD Process of Technological Innovation



problems identified with the 6.1-6.3 portion of the DOD technological innovation process were (a) matching needs event No. 4 (Figure 5) with feasible ideas; (b) generating an environment for creative ideas; (c) achieving productivity from government R&D laboratories; (d) lack of strategic thinking on the application of technology; and (e) lack of funds to properly support ideas from government and industry R&D laboratories. Later in this study we will address causes and solutions for the above problems.

Factors Contributing to Technological Innovation

The DOD process model (Figure 5) becomes relevant when it permits us to identify factors that cause success or failure. There is now a substantial amount of evidence to support the importance of a number of factors when you sum the references used in the study. However, there will always be exceptional cases where the benefits accruing from an innovation are so outstanding that it succeeds in spite of poor management. An inventory of this critical factor in the innovation process should include the following:

1. Need Orientation (versus Requirement Orientation).
2. Relevance to the Organization's Objective.
3. An Effective Selection and Evaluation System.
4. A Source of Creative Ideas.
5. Organization Receptive to Innovation.
6. Commitment by a Few Individuals.
7. Supply of Management Skill (Technical Skills Plus).
8. Suitable Information Channels.

If decisions are made with an understanding of the processes at work and within a conceptual framework, they will be better decisions. The following chapters will attempt to develop such a conceptual framework.

CHAPTER II

FOOTNOTES

1. Sumner Myers and Donald Marquis, Successful Industrial Innovation, 1969, p. 3.

2. Ibid., p. 5.

3. Joel D. Goldhar, Louis K. Bragaw and Jules J. Schwartz, "Information Flows, Management Styles, and Technological Innovations," IEEE Transactions on Engineering Management, February 1976, p. 55.

4. Ibid., p. 53.

5. Myers and Marquis, p. 7.

6. Ibid., p. 27.

CHAPTER III

TECHNOLOGICAL FORECASTING

> Forecasts of the weather, agricultural production growth, industrial production, markets, sociological change, government spending, economic conditions, political attitude and many other attributes of future conditions are regarded as essential to planning wisely. . . . Strangely society has been very slow in coming to grips with the forecasts of technology.
>
> James R. Bright[1]

Forecasts give us clues on what the future may hold. We all know DOD managers need to use any clues they can find to the best of their ability. Marketing forecasts are prepared based on the sale of technology. But somehow technology forecasts are called "best guess" with a full share of critics.

Let us consider two reasons why DOD should place a greater emphasis on technological forecasting. First, the forecast must be part of the R&D manager's plan when he considers the environmental trends in assessing what the organization might do. Secondly, the forecast offers part of the answer for our problem of minimizing disfunctionalization in revolutionary and evolutionary innovations.

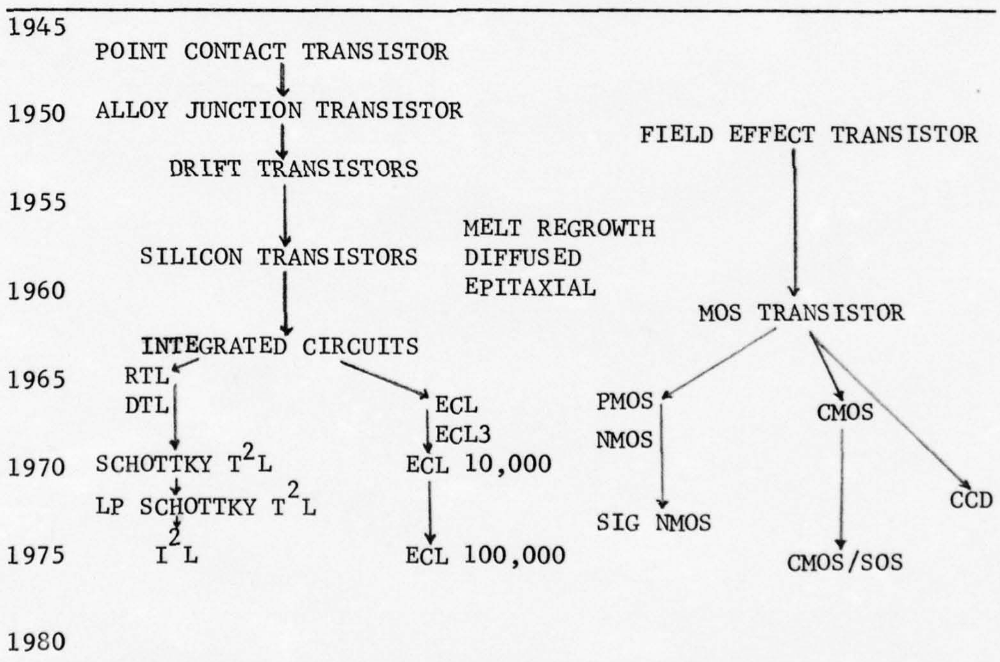
R&D strategy formulation is viewed as the process of moving from what the organization <u>might do</u> considering environmental trends, through what the organization <u>can do</u> considering an analysis of its capabilities, to what the organization <u>should do</u>.

The one thing that makes Electronic Systems R&D so unique is the environment. Electronic technology has been progressing at an extremely dynamic pace and seems likely to continue at a steadily

increasing pace. The technological progression of Figure 6 shows vividly change in the transistor which has paced electronic technology.[2] If you have difficulty with some of the titles like "Si G NMOS," you share a problem with many engineers and electronic system manager. In this study the important thing about the nomenclature of Figure 6 is that each new nomenclature represents a new level of performance.

Figure 6

Technological Progression



Here each new transistor technology has offered a 5-10 to one increase in some performance measure.

The environmental trends faced by R&D managers includes much more than technology, but for technology the forecasting techniques and forecasts are prepared by private industry. Other environmental

factors are sufficiently unique for each DOD system that we are not so fortunate.

Technological Forecasting Techniques

The following are the major technology forecasting techniques in use today:

- Trend-Extrapolation
- Delphi Technique
- Goal-Oriented Structural Technique
- Monitoring
- Dynamic Modeling
- Cross Impact Analysis

Of these techniques Delphi and Trend-Extrapolation are the most frequently used. The extrapolation of past trends into the future is a technique economic forecasters have used for many years. Some varieties of the trend-extrapolation concept are: (1) parameters of technology (figure of merit trends), (2) precursor event or leading indicators, (3) analogous precedents, (4) envelope S curves, and (5) technological progress functions.

The Delphi technique is based on predictive statements circulated to a group of experts with successive rounds of feedback, reasoning, and counter-arguments. The major conditions for Delphi are anonymity (to eliminate the interpersonal social problems), feedback, and statistical control.

Current Forecasts for Electronics

The Forecast of Table 2(a) is a trend extrapolation.[3] Table 2(b)

in contrast was prepared with a modified Delphi technique.[4] These tables show the real contrast between the two techniques because trend-extrapolation is best used for short-range forecast. Delphi on the other hand is best suited for long-range forecast.

TABLE 2(a)

BUBBLE MEMORY PROSPECTS

Characteristics	1976	1978	1980
Bubble size	4-6	2-3	1
Density (bits/in.)	10	10	10
Speed:			
data rate (MHz)	0.1-0.25	1	1
access time (ms)	10	1	1
Module capacity (bits)	10	10	10-10
Storage medium	garnet	garnet	garnet amorphous film
Lithography	optical	optical, conformable printing	optical, conformable printing electron beam X-ray
Device configurations	T-bar	gapless T-bar	gapless T-bar continuous disk bubble lattice
Application examples	POS system calculator	space-flight recorder, main memory extension	large file data base
Competition	CCD, FET	CCD BEAMOS fixed-head disks and drums	CCD BEAMOS moving head disks

One word about the way technology becomes revolutionary that has a bearing on forecasts. Our revolutionary innovation stems from technology transfer between disciplines. The transistor resulted from transfer of knowledge from research, and metals and chemistry that permitted semiconductor advancement. Predicting when and where

TABLE 2(b)

KEY AREA FORECASTS

	1975–1978	1979–1981
Components and devices	• Some CCD memories • Large-capacity bubble memories (10^{10}b/in²) • I²L logic for consumer and instrument applications • Wider use of liquid crystal displays • LEDs as displays in most instruments • Finer ion-implantation processes	• Flat-panel plasma displays • Maturing of microprocessors • CCD TV cameras • CCD IR imagers • IC CCD chips with imaging and signal processing on the same chip • Commercial ICs with 0.5-micron lines using E-beam/X-ray lithographic techniques • IC logic with 100-ps rise times
Computers	• Hard software, packaged application programs in semiconductor chip form • Microprocessor-based computer systems for small businesses	• Low-speed, low-cost optical character recognition devices • Computer-based medical diagnosis • Microprocessor-based urban traffic control
Communications	• Electronic multiplexers and concentrators in telephone local loops • Time-division multiplex switching for data communications	• Direct satellite channels for data users • Single carrier per channel and time division multiplex equipment for satellites • 18–23-GHz earthbound microwave links
Instruments	• Economically feasible digital delay lines to store A/D converted signals for display and analysis • Economical solid-state instrument program and data storage, without battery backup • Economical dedicated annunciator panels such as custom liquid crystal displays • Lower-power, lower-cost alphanumeric multiple character displays with some autoscan logic integrated into them • Commonplace hard copy for permanent human readable records • Programmed logic in decreasing-cost instruments • Inboard microprocessors in all moderately priced analytical instruments	• Lower-cost sensors • Industrial data terminals in easily portable sizes • CMOS-SOS in hand-held DVMs and portable data terminals, all battery operated • Frequency conversion (GHz to kHz), security monitoring, data handling, and instrument programming using CCD TV cameras to read CRT oscilloscope images • IR imagers in instruments used for studying live tissue samples • Reading and executing progress from optically stored data on cards (combined microprocessor and CCD imager) • High-speed, real-time counters at the price of today's 15-MHz general-purpose counters

1982–1984	1985–1987	1988–1990
• High-reliability AlGaAs laser diodes permitting long-distance optical telecommunications lines in the 0.8–0.9-wave-length region • Wider use of aluminum and aluminum alloys to replace copper • GaAs and InP materials for devices operating in THz range • Instrument preprocessors using optical methods for signal processing (e.g., *transforms, correlations*)	• Electrochromic computer and instrument displays • CPUs using cryogenically cooled Josephson-junction devices • FETs with 1-ns switching speeds • Solid-state traveling-wave amplifiers	• IC functional densities to line *widths of 0.1 micron or less*
• Fault-tolerant long-lived computer system modules • Intelligent CRT terminals for general office use • Electronic office files and communications	• Home computer terminals connected to telephone communications • Computer optimization aids for consumers • Computer-controlled artificial organs	• Practical voice-operated typewriters
• 900-MHz portable telephone systems in urban areas • Fiber optic telephone trunks • Low-cost microwave equipment for short-haul use	• Digital encoding of subscriber telephone signals • Predominantly digital earthbound microwave equipment • 30-GHz satellite transponders	• Beginnings of local loop telephone service offering 6-MHz bandwidth
• Higher-level microprocessors in instruments • Reliability limitations to future growth in instrumentation capabilities • Optical data busses for instruments • Continued reduction in cost and size of microwave-based instruments for velocity and distance measurement, auto collision avoidance, etc. • Practical optical computers • Measurement "service bureaus"	• Drastically reduced manufacturing costs to produce man–machine interface components—more communication for less cost in instruments • High-frequency waveform synthesis, high-speed multiplexing applications, and increased time and amplitude accuracy in gating sample and hold. Very high speed D/A converter systems based on pulse duration approach • Continued expansion of microwave use in distance measuring and collision avoidance applications, as well as reduced cost, increased stability (and lifetime) microwave sources for calibration and test functions	• Microprocessors for almost any instrument application • Expansion of IC manufacturers into the high-volume, bench-top instrument business • More compact instruments with more capability (voltmeter in a wristwatch case; oscilloscope in a probe, perhaps with "eye glass" display) • New functions (heart-rate and arrhythmia counters with a tie-clip-size package, blood-pressure meters built into a wristwatch band, etc.) • Digital signal processing in a hand-held voltmeter

this technology transfer will occur is the worst problem facing forecasters.

As we look at the DOD Budget (Table 3), it is clear that DOD will shape future technology with selected programs. The areas of technology in Table 2 are influenced mostly by private and commercial consumers. DOD electronic systems must be prepared to reply on the technologies of the consumer market and interface with other DOD systems. The strategies for dealing with the rapidly changing technologies is subject of the next chapter.

TABLE 3

WEAPONS R&D FUNDS
(Millions of Dollars)

	FY 77	FY 78	Contractor
ARMY			
Advanced Attack Helicopter (AHH)	$130.8	$200.0	Bell
AFAADS air defense	0.2	24.2	
Ballistic Missile Defense Technology	100.1	107.7	McDonnell
BMD Advanced Technology	102.7	107.3	Multiple
Helifire, heliborne missile	17.8	50.5	
Patriot (SAM D), surface air	180.2	214.6	Raytheon
SSM, surface-surface missile	5.0	30.1	
Tri-Tac, joint tactical communications	37.3	58.9	GTE-Sylvania
NAVY			
V/STOL aircraft developments	44.0	101.1	Multiple
LAMPS ship helicopter	73.7	107.3	Multiple
AEGIS, surface-air	26.3	27.2	RCA
HARM, air-surface radiation	30.0	29.7	TI
Tomahawk, sub/air-launched missile	119.5	234.3	General Dynamics
SES, surface effect ship	48.0	43.9	Rohr Ind
Advanced ASW Torpedo	18.0	26.5	
ELF communications	14.8	23.7	
Wide Aperture Array Sonar	9.2	23.1	
AIR FORCE			
Advanced Medium STOL	29.3	25.0	McDonnell Boeing
E4AABNCP, command post	98.7	65.8	Boeing
*NATO AEW&C aircraft (E-3A)	0	15.7	Not Selected
Precision Location Strike System	12.0	30.2	Not Selected
*RF-X, tactical air recon.	0	1.0	
*Advanced MR missile, air-air	5.0	42.5	Multiple
*GLCM, ground-launched missile	0	3.9	
*MX, MIRVed ICBM	69.0	294.4	Boeing
*WVR missile, air-air (AIM 9L folo)	0	5.9	Not selected

* New R&D start

CHAPTER III

FOOTNOTES

1. James R. Bright, A Brief Introduction to Technology Forecasting, p. 1-1.

2. David Shore, "On Being Run over by Technology," Government Executive, January 1977.

3. Donald Christiansen, "Time and Technology: Looking Ahead in Electronics," IEEE Spectrum, January 1976, reprint number x75-041.

4. Laurence Altman, Memories Electronics, 20 January 1977, p. 96.

CHAPTER IV

STRATEGIES FOR RESEARCH AND DEVELOPMENT

> One of the great strategies of science and technology is to do the easiest things first. Well, we've been doing that for about 100 years now, and the problems have become much tougher.
>
> Dr. William O. Baker, President
> Bell Telephone Laboratories, 1974

Classical Views

In studying strategies we must focus specifically on Electronic Systems, but we should first identify what is meant by strategy. First, to ensure no misunderstanding of what is involved in the national strategy of technology, the proper view is best captured with the following:

> There are no battles in this strategy; each side is merely trying to outdo in performance the equipment of the other. It has been termed "logistic strategy." Its tactics are industrial, technical and financial. It is a form of indirect attrition instead of destroying enemy resources, its object is to make them obsolete, thereby forcing on him enormous expenditure. . . .
>
> A silent and apparently peaceful war is therefore in progress, but it could well be a war which of itself could be decisive.
>
> General d'Armee Andre Beaufre

Whereas this study deals with R&D strategies, it should be obvious that R&D strategies are not only part of the national technological strategy--they are the main ingredient.

The process of R&D strategy formulation will consist of those items mentioned in the previous chapter. First, what the organization <u>might do</u> considering the environment and the forecast. Secondly, we

must consider what the organization <u>can do</u> considering an analysis of its capabilities. Since most of DOD R&D projects are executed by private companies, a major point of this study can be emphasized. The preceding chapters have dealt with many findings of private R&D activities. However, these private companies offer capabilities for DOD. Most developments or products of the forecast of Table 2 will offer capability for DOD. The third and final part of the R&D strategy formulation is what the organization <u>should do</u> considering alternative threats and opportunities.

Private Enterprise R&D Strategies

The spectrum of possible ways technology can be brought to bear in implementing a strategy cover a limited range. This range includes: applying state-of-the-art, competing technology, extending the state-of-the-art, and adapting emerging new technology.

<u>Applying State-of-the-Art</u>: In electronic systems R&D state-of-the-art work offers a wide range of opportunities because it depends on characteristics of component technologies like transistor, integrated circuit, or micro-processors. Through imaginative application of components in products and subsystems, good rewards are possible. However, state-of-the-art technologies are open to competition and actually stimulate competition.

<u>Competing Technology</u>: This strategy emphasizes viability of competing technologies to those favored by competitors. The dilemma of which technology to focus on is a most difficult problem.

Consider Figure 7 where we now rest at year 5 (once again, the nomenclature is not important). Unit cost goes down as activity goes up according to Figure 8. The most difficult aspect of the problem is the need to appraise the relative futures of the alternative technologies including the paths of the curve for growth, decline and improvements.

Extending the State-of-the-Art: The idea of a strategy that involves extending the state-of-the-art brings thoughts of great risk and even horror to many. Virtually any product design or process offers opportunities for improvement that reduce cost or improve performance and every business should assume that its competitors will make such improvements. The extend to which the change is pursued is based on what firm perceived as necessary in seeking a competitive advantage. A parallel consideration is the rate change in customer demand. If demand is escalating rapidly, larger incremental improvements are necessary but the larger the increment the greater the risk.

Adapting Emerging New Technology: Consider the activity curve of Figure 7 (I^2L, SOS, or CCD) that peaks at about the 9th year. Pioneering applications can produce unique advantages in the market that give the firm great leverage over competitors. Although the trend-extrapolation is fairly evident, the proper candidates among competing technologies is difficult to anticipate.

Figure 7

Activity Curve of New Technology

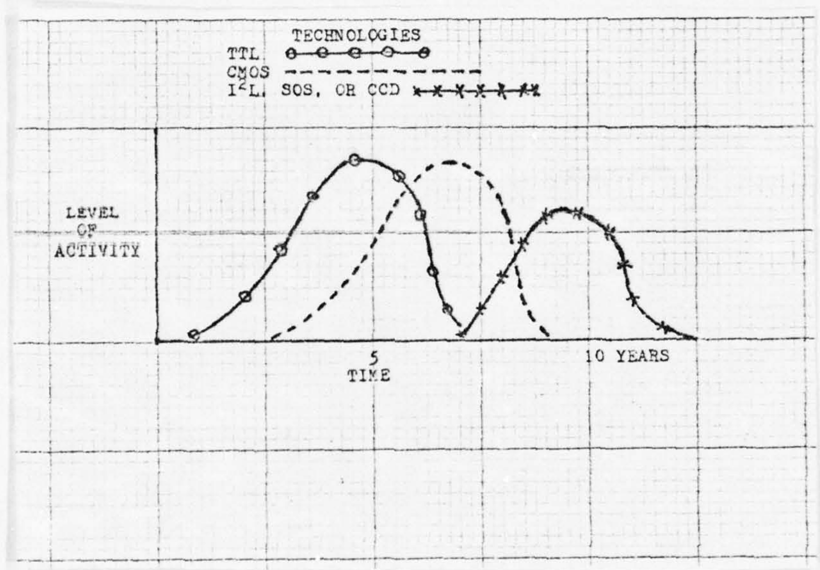
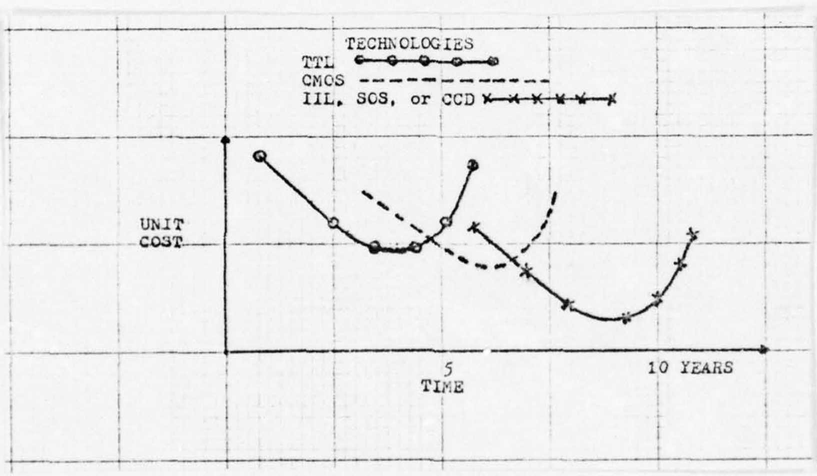


Figure 8

Alternative Activities Technology



Market Strategy

Combined with each of the technological strategies each commercial enterprise must select a market strategy that is coherent with corporate objectives. Common options cover a wide range that can be divided into the following broad categories:

Defensive/Hold Harvest

Offensive/Growth

Diversification

Others

Defensive/Hold Harvest: The defensive strategy is suitable for a company able to earn profits under conditions of competition. The enterprise must hold its share of the market and harvest sustained profits through low manufacturing cost. This strategy puts emphasis on cost reduction in applying present state-of-the-art.

Offensive/Growth: This high risk, high potential payoff strategy demands technological innovations that extend the state-of-the-art. The strategy requires acquisition of new markets based on development, or innovations that improve performance or cost.

Diversification: The capture of associated markets require innovations that adapt emerging new technology.

Other Strategies: The opportunities for mixtures of the above strategies are numerous. Some additional unique strategies include the following: (1) licensing or buying the fruits of another company's innovations; (2) interstitial strategist seeks weak points

in the market; (3) maverick strategist exploits innovation ready to go on the market; and (4) people strategist acquires people with knowledge of company's innovations.

Implications of Private Strategies on DOD

Consider a summary of the strategies discussed in the context of a matrix as shown in Figure 9. Studies of commercial enterprises show their dominant correlation follows C in Figure 9.[1] Interviews with the representative of Appendix I represented a clear DOD trend that follows the Ds of Figure 9. When you consider the bottom line of the matrix, it is not surprising that most DOD contractors are not adapting technology at the pace of commercial electronic systems developers.

Figure 9

R&D Strategy Matrix

Market Objective / Technical Strategy	Defensive Hold & Harvest	Offensive Growth	Diversification
Apply State of the Art	C D		
Extend the State of the Art	D	C	
Competing Technology	D	C	C
Adapting Emerging Technology	D		C

C = Commercial enterprise
D = DOD

In interviews (see Appendix I) each was asked if the unique problems facing electronic system R&D managers don't tend to force this discipline into a favored strategy. A consensus among the group was that DOD must focus on a strategy of competing technologies for electronic systems that face the threat of obsolete technologies going into production. In chapter III we made the point clear that electronic component technologies tend to span a period of five years. As an R&D program technology nears the end of life for the selected technology, the problems really mount up. First, available vendors reduce (sometimes reducing quality) while prices and delivery times increase. Secondly, guarantees for long terms of availability of spare parts fall out. Thirdly, the emerging technologies consistently offered higher performance at lower cost.

Electronic Systems Life Cycles-- Hardware vs. Soft/Firm Ware

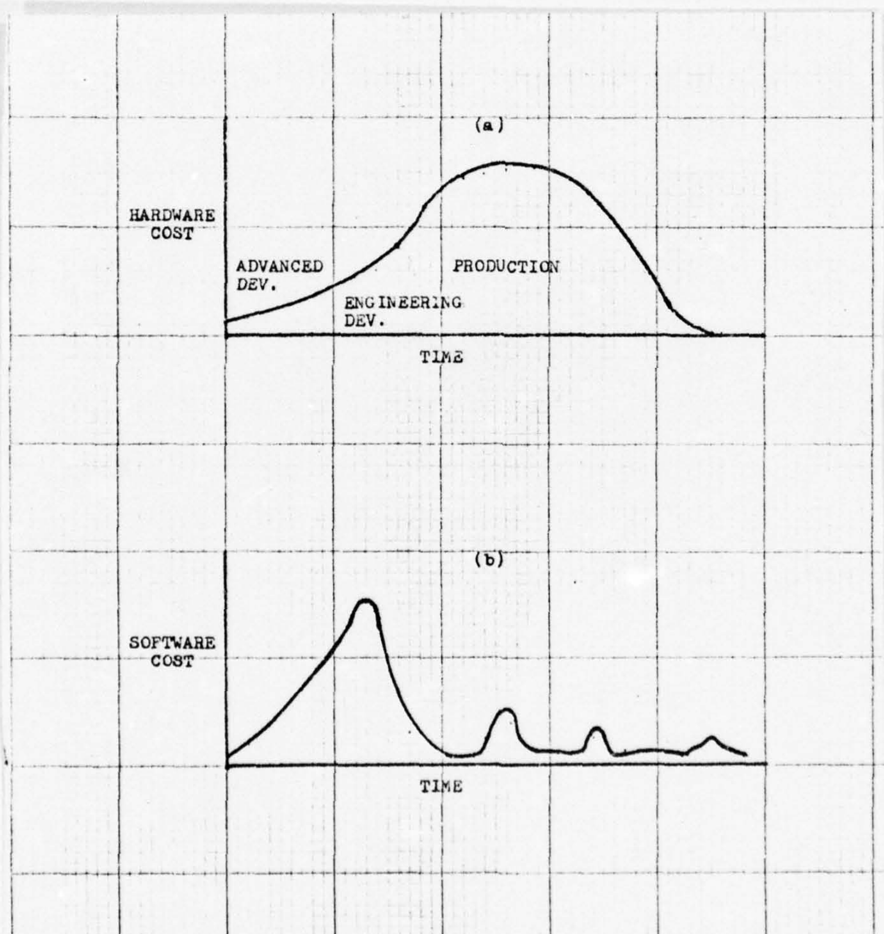
For electronic systems we are undergoing a change where software and firmware development expenditures are greater than hardware costs. We are also seeing production costs losing ground to R&D as a percentage of life cycle cost. Figures 10(a) and 10(b) show the change of cost trend dramatically if you can picture them super-imposed.

The selection of an R&D strategy for a multimillion-line software system is far too difficult to identify one strategy. Here you must use all the strategies of Figure 8 plus some.

On the subject "Software engineering takes hold," three approaches are considered for the multimillion-line software system

Figure 10

Electronic Systems Life Cycles



or suggested.[2] First, a new kind of person called the "software engineer" is used to tackle the problem. Secondly, a new discipline and new breed of organization is occupied on the major source of past problems--software errors stemming from incorrect and ambiguous specification. Sixty percent of past software errors have stemmed from incorrect and ambiguous specifications.[3] Thirdly, configuration control procedures in force on hardware for years is being emphasized to prevent propagation of errors through the entire software development process.

> Tomorrow's illiterate will not be the man who can't read; he will be the man who has not learned how to learn.
>
> Psychologist Herbert Gerjuoy
> Human Resources Research
> Organization

CHAPTER IV

FOOTNOTES

1. Lowell W. Steele, Innovation in Big Business, 1975, p. 89.

2. Howard Falk, "Computer: All Pervasive," IEEE Spectrum, January 1977, p. 42.

3. Ibid.

CHAPTER V

DOD R&D RISKS, BARRIERS AND ASSESSMENT

> People like progress--but dislike change.
> Since the primary purpose of the R&D manager is
> to devise, plan for, and initiate change he
> must be accustomed to judging the degree to
> which change will reflect improvement.
>
> Robert O. Burns

There is no common genesis of R&D management problems. They originate internal to the organization, external, and all kinds of mixtures of internal and external. As Dr. Burns points out, some are as simple in origin as the fact that people dislike change. Research and development is a risky investment, but many corporations have learned that enormous profit can result from successful innovations. Here we want to focus on the unique risks and barriers faced by the DOD R&D managers.

Meyer and Marquis data on innovations from five industries showed 53% of their innovations were new items and the remaining 47% modifications. Table 4 shows the range of benefits from the innovative modifications for the five industries studied by Meyer and Marquis.

TABLE 4

NATURE OF INNOVATIVE MODIFICATIONS

Modification	Percent
Improved esthetics	3
Increased utility	19
Increased durability	5
Increased efficiency of performance	40
Lowered production cost	13
Other improvements	20
	100

We can see from Table 4 that the benefits from innovations in the commercial sector are not significantly different from benefits DOD managers seek. The three percent improved esthetics innovations are not likely in DOD, but three percent is a small percentage. Marketing pressures surely were involved in those industry modifications classified as improved esthetics.

C. Wilson Randle's Harvard Business Review article, "Problems of R&D Management," shows in his survey of 100 major companies where the median R&D failure rate was 67%. "Failure here is defined as projects instituted and designed for market appearance that never reach the market place." His survey included industries developing consumer goods where the life cycles are relatively short, but the DOD problem is of no less acute dimensions.

$$\text{R\&D INDEX OR MERIT } I = \frac{B}{C} \times P_e \times P_c$$

The above index was developed for small simple products, and still one must question whether it has experienced any practical utility. The simple formula can help in defining risk. B is for benefits and identifies one broad category of risk. C is for Cost, a risk factor which seems to carry all other factors as dependent variables. P_e is probability of technical success and P_c is the probability of commercial success. In the DOD context P_c would be equivalent to P_{rd}, the probability of a successful requirement determination.

Since this study focuses on the innovation process, let's consider some aspects of the technical risk with broad implications.

Lowell W. Steele classified R&D in terms of Risks with the following:[1]

(a) Apply the State-of-the-Art - (Low Risk)
(b) Extending the State-of-the-Art - (High Risk)
(c) New Technology - (Higher Risk)
   (1) New technology applied to established functions
   (2) New technology permitting a new function

To evaluate DOD R&D risks we must separate electronic system technology from electronic component technology. Steele's increasing risk levels may be applicable to electronic system technology but not electronic component technology.

Applying the State-of-the-Art: The short life spans of electronic component technology add a new meaning to state-of-the-art. Figure 7 (page 33) shows that state-of-the-art can be a point on a component activity curve. If the state-of-the-art changes each month, what shall we apply as "present state-of-the-art"?

Extending the State-of-the-Art: With electronic component technology, to extend the state-of-the-art means refining the design so the design will be more competitive with new technologies for meeting unique subsystem needs. The risks of obsolescence is reduced as state-of-the-art is extended. Technical risks are dependent on the level of the state-of-the-art extension effort.

New Technology Applied to Established Functions: The best way to combat obsolescence is to apply new emerging technology. Here we must deal with the risks that an emerging technology might never emerge and become a mature technology. The strategy of competing

technologies is a necessity in dealing with new technology.

New Technology Permitting New Functions: Most new technologies in electronic components offer considerable performance benefits when applied to established functions. Capabilities permitted by technologies can be devoted to new functions that help "disfunctionalization." Built-in facilities for training and maintenance diagnostics are examples of technology minimizing the impact on personnel functions.

David Fishlock's work on the risks and rewards of research and development produced ten rules for success based on an analysis of costly R&D failures. Management in the projects studied were overcome by risks. These risks can be stated as follows and not in priority order.

1. Being overambitious.
2. Underestimating lead times.
3. Ventures in isolation from requirements.
4. Research and industry manufacturing drifting apart.
5. Underestimating the scientific mind.
6. Not ensuring venture has a natural leader.
7. Not ensuring venture has all the management skills it requires.
8. Not thinking through the financial consequences.
9. Making prototypes that mask problems.
10. Not being prepared to explore a new idea.

Risks for the DOD Manager

Interviewees of Appendix I were asked to comment on whether DOD program rewards match the risks of being innovative. All stated that DOD rewards to the individual DOD managers don't match the risks of making technological innovations. They also reported that rewards don't match the risks of making technological innovations for contractors. Given the perception that we have a problem in this area, the range of definitions and attitudes was wide. Whether right or wrong, reported below are views with multiple supporters in the group interviewed.

1. No Reward and Many Penalties. Not only are there no significant rewards for technological innovation, but the penalty increases almost in proportion to the risks,and rewards remain low.

2. Loss of Opportunities. DOD is impacted most in managing the risks of technological innovation by lost opportunities for lower cost, increased efficiency, performance, etc.

3. Use Civilian Project Managers. Compared to their counterpart on the contractor's team, many military project managers have not experienced enough projects to take those risks in the best interest of the government. In many cases excessive concern existed that complexity and sophistication of the high technology solution would mask the risks.

4. Innovative Ideas in Proposals at a Disadvantage. In the contract proposal the really innovative solution is at a

disadvantage to the conventional solution even as an alternate because of risks.

<u>Innovative Solution Must Be Proprietary</u>: The development of an innovative solution offers few advantages to the contractor when the proprietary nature of the innovation cannot be used as an advantage over his competitor.

Barrier

Steele grouped the barriers to communication in R&D in three levels which are technical barriers, perceptional barriers, and value barriers.

<u>Technical Barriers</u>: DOD does and will continue to experience technical barriers. Engineers and scientists work and think as if most problems are solvable. If reasonable and specific constraints are placed on their problems, barriers are sometimes formed that only time will help cross.

<u>Perceptual Barrier</u>: These barriers are not easy to define except to say people take different views of ideas. Ideas form the cornerstone of the innovation process; therefore, it is understandable that different perceptions will surface from oversimplifications, misinterpretations, misunderstandings, etc.

<u>Value Barriers</u>: People have different life styles, and so they acquire different value systems as a consequence of very complex circumstances. Differences in the relative worth of achievements are deeply rooted in individual behavior and thus are a barrier.

Positives and Negatives

One of the goals of this study was to perform a critical appraisal of the DOD technological innovation activities in the light of research performed doing the study. To perform this task the author has elected to use a two-part R&D profile. Part I of the DOD profile is composed of a grading of criteria of the type used in private industry. Part I of the DOD R&D profile is a subjective grading by the author. The grading takes the following into consideration: (1) differences between private industry and DOD innovation processes discussed in chapter II; (2) distribution of costs in successful commercial product innovations (Figure 4, page 16); (3) DOD process observations (page 17); (4) the technological forecast of Table 2 (pages 25, 26, and 27); (5) the implications of private strategies on DOD (page 31); (6) the interview discussions of DOD risks (page 45); and (7) all interview discussions at Appendix I.

Part II of the DOD R&D profile is based solely on the interviews of Appendix I. In these interviews the questions of Appendix II were used to initiate discussion. All interviews were conducted on a nonattribution basis; therefore, the sources of remarks in Part II of the profile cannot be identified.

The intent of this profile is to form an appraisal of DOD R&D and technological innovation from the eyes of those involved in electronic systems R&D management.

DOD R&D PROFILE

Part I

EVALUATION FACTOR	Very Good	Good	Average	Poor	Very Poor
R&D Criteria					
1. Current R&D Strategy and Long-range Plans			●		
2. Attitude toward Risk					●
3. Attitude toward Innovation				●	
4. Timing Sensitivity			●		
5. Estimate Product Life				●	
6. Probability of User Success			●		
7. Effect upon Current Product			●		
8. Cost and User Acceptance			●		
9. Distribution Channels		●			
10. Estimating Launching Cost				●	
11. Probability of Technical Success	●				
12. Development Cost and Time				●	
13. R&D Resource Availability	●				
14. Applying New Technology				●	
15. R&D Cost				●	
16. Competition			●		

DOD R&D PROFILE

Part II

Factor	Remarks
1. Current R&D Strategy and Long-range Plans	"No one in Dept of the Army R&D has the job of strategic thinker."
2. Attitude toward Risk	"Your program managers have no incentive to take risk."
3. Attitude toward Innovation	"Innovative ideas are at a disadvantage and especially as unsolicited proposals."
4. Time Sensitivity	"DOD's biggest problems pertaining to innovation are lost opportunities."
5. Estimate Product Life	"We always develop equipment like it will never become obsolete."
6. Probability of User Success	"Most DOD programs go on to the user, pressure groups make them hard to stop."
7. Effect upon Current Product	"DOD does not plan for transition to new systems and interfacing sufficiently."
8. Cost and User Acceptance	"More innovations are needed to keep the cost down and performance up."
9. Distribution Channels	"The DOD logistics system is good considering the magnitude of the job."
10. Estimating Launching Cost	"DOD design to unit cost targets have little if any performance risks."
11. Probability of Technical Success	"Probability of technical success is program dependent but always high."
12. Development Cost and Time	"When will DOD learn that technological innovations are the way to reduce cost?"

Factor	Remarks
13. R&D Resource Availability	"We need more flexibility with both funds and manpower ceilings."
14. Applying new Technology	"In managing technological innovations DOD is impacted most by lost opportunities."
15. R&D Cost	"Cost growth with inflation is a continuing problem."
16. Competition	"Competition brings ideas from where you expect them. But good ideas come from where you don't expect."

In this chapter we have investigated risks, barriers and assessment. One of the goals of this study was to perform a critical appraisal of DOD technological innovation. This appraisal was formed on the basis that: (a) DOD technological innovation is a true subset of technological innovations for all science; and (b) technology and electronic system innovation is a subset of DOD innovation. This association of sets and subsets means this appraisal should be representative for all DOD R&D and it surely is representative of Electronic Systems R&D. The following chapters will help focus on what DOD should do.

CHAPTER VI

TECHNOLOGICAL INNOVATION TO PRODUCTION

Industry Independent Research and Development

Contractors are provided independent Research and Development (IR&D) funds to strengthen our technology base and acquire options from that base. However, the question that continues to surface is, What returns are we getting on technology base dollars?

The statements by the Director of Defense Research and Engineering to the 94th Congress made the point clear that we expect IR&D funds to provide competence for industrial competition.[1] Here, we want to consider the internal industrial decision process for IR&D activity. The participant and duties in a typical IR&D planning cycle are as follows:

Participants	Tasks
Research Advisory Committee	Review of Forecast critical technology
	Review company's technology base
	Issue technology base document
Research & Advanced Projects Managers	Study Customer requirements
	Develop IR&D programs applications
	Coordinate long-term technology needs
Engineering Program Managers	Establish IR&D preliminary bogies
	Formulate product area plans

Participants	Tasks
Principal Investigator	Generate new IR&D task descriptions
	Submit task description to Engineering Program Managers
Marketing	Complete integrated 5-year program plans
VPs Engr, Marketing & General Manager	Review plans

Given that an industrial organization has a planning cycle consisting of interaction among the above IR&D planning participants and given that programs are identified according to the program summary of Figure 11, what are the gut issues? Interviewees were asked to identify the continuing problem faced by their R&D managers. A summary of the problems discussed is as follows:

1. Personnel obsolescences.
2. Knowing the state-of-the-art and direction of technologies.
3. Getting sufficient staffing for projects,
4. Getting support for new projects.
5. Justifying capital equipment.

According to most of the interviewees, 70% of the IR&D funds are applied to short-range solutions and problems. In other words, the sophisticated IR&D planning cycles of DOD contractors seem to be a tactical approach to technology rather than a strategic approach.

Computer Software Development

Exploratory development and advanced development require 12%

Figure 11

IR&D Program Summary

PROJECT NAME:

PERFORMING ORGANIZATION:

EXPECTED FUNDING SOURCE:

PROJECT WRITER:

PROGRAM MANAGER AND PRINCIPAL INVESTIGATOR:

TECHNICAL PROBLEM/ISSUE:

TECHNICAL OBJECTIVE:

TECHNICAL APPROACH:

SCHEDULE: MAN MONTHS FOR FY 77/78
KEY MILESTONES

OUTPUT: TECHNICAL REPORT, MODEL, RESULTS, etc.

CUSTOMER RELATIONSHIP:
CUSTOMER AWARENESS & ACCEPTANCE--AGENCIES IMPACTED

BUSINESS PLAN IMPACT:

PRIORITY:
IMPACT OF GO/NO GO DECISION:

FINANCIAL:

and 19% of the DOD R&D T&E budget respectively.[2] The single most pressing problem inhibiting progress in these phases for major electronic systems innovations is the failure to achieve combatibility between software and hardware. All major electronic systems are becoming computer controlled with some requiring the development of nearly a million lines of software. Figure 12 shows the contrasting hardware-software schedule outlines. The decision points that are optimum for evaluating the hardware may not be optimum for software and vice versa. We must select software or hardware optimum evaluation points which proceed peaks in activity and cost.

> However, even as the production line begins
> to hum, the innovation process is not over,
> . . .
>
> Kenneth G. McKay
> Executive Vice President
> Bell Laboratories

Much to the dismay of scores of R&D critics, all R&D has a distance goal of production. Granted, some people's perception of the distance is hard to visualize. The question here is, How do we get to the hum of the production line with revolutionary and evolutionary innovations? Unfortunately there are no complete check lists of do's and don'ts. I suggest we approach the question by identifying basic truths of the transition to production.

<u>Innovation to Production Truths</u>

1. Absolutely stable designs are the dead ones.
2. The proof is in the testing.
3. Old problems never die, they must be fixed.
4. Facilities are crucial.

Figure 12

System Acquisition Phase

HARDWARE

Breadboard Experimental Prototype	Brassboard Advance Development Prototype	Engineering Development Prototype	Initial Production Items	Full Production Items

SOFTWARE

Decision I

Requirement

System Design
Functional

Decision Point II

Program
Increment I

Decision Point III

Program
Increment II

Decision Point III

Program
Increment III

USAGE
Refinement

5. Symptoms are much easier found than the real problem.

6. Know-how is a must.

7. Products will consistently be no better than their documentation.

8. Murphy's Law lives on manufacturing.

CHAPTER VI

FOOTNOTES

1. Dr. Malcolm R. Currie, the Department of Defense Program of Research Development, Test and Evaluation, FY 1977, Statement by Director of Defense Research and Engineering to the Congress of the United States, 94th Congress, Second Session, 3 February 1976, p. IX-4.

2. Ibid., p. A-6.

CHAPTER VII

RECOMMENDATIONS AND CONTINUING PROBLEMS

Now that you have read the preceding chapters of this study, it is time we get to the gut issues. What have I done? Based on the thesis in the introduction, I have studied published works on technological innovation in private enterprise and discussed the relevance of their findings to DOD R&D for electronic systems. I have talked to people working in R&D management positions from various organizations (both government and industry) and summarized their comments and observations.

The positives and negatives for the subject R&D were articulated in chapter V. In this chapter I will spell out recommendations of what we should do, but, first, the findings and conclusions.

Summary of Major Findings

1. Based on a review of DOD technological innovation activities and a review of relevant literature, a model of the DOD technological innovation process was developed as presented in chapter I. An analysis of the DOD technological innovation process model resulted in the identification of eight contributing factors also presented in chapter I.

2. Technological forecasts reviewed in chapter II clearly showed technological innovations will spark continued rapid progress in electronic technology through 1990.

3. Implications of private industry R&D strategies on DOD were examined in chapter III, and the main differences were shown between

DOD R&D strategies and those of private industry. The main difference relates to the determination of organization objectives.

4. In chapter V risks and barriers that impact technological innovation in DOD were identified and examined. The examination revealed that DOD attitudes towards risk were significant and a hinderance to innovation.

5. An assessment of DOD technological innovation and general DOD R&D management was performed in chapter V in the form of a DOD R&D profile. While the profile shows some positives and negatives, the overall profile is not as good as most DOD organizations have the potential for being.

6. All other findings of this study can be identified as helpful information for DOD R&D managers.

Conclusions

Attitudes toward risk are the major differences between DOD and private industry technological innovation processes. Other differences do exist between the technological innovation processes of DOD and the private sector as discussed in chapter II (pages 10-21). These differences are not sufficient to cause DOD electronic systems to contain obsolete critical subsystems when they enter the field. In contrast, most commercial new systems and subsystems pace the state-of-the-art when they enter the field.

For example, Table 2 (page 25) shows that magnetic bubble memories will be competitive with disk and drum computer memories by 1980. Research into the computer subsystems of the major DOD R&D

programs in Table 3, page 28, showed none are likely to introduce these new magnetic bubble memories. More significantly, most of the major DOD R&D programs (see table 3) will field obsolete computer memory subsystems.

The most significant of the problems surfaced in this study is that of dealing with technical obsolescence. Approaches for coping with short technology life spans and technical obsolescence are identified as:

Design to emerging technologies. Establish competition between emerging technologies by designing to at least two emerging technologies in critical systems.

Design to most active technology. Determine the most active technology in terms of commercial sales and design to that technology. This approach requires that we take the risk of becoming unsupportable in terms of replacement parts. This risk can be reduced with a long-term contractor support agreement and captive lines. However, once the captive line becomes obsolete, it is hard to tell who is the captive.

Programed technological innovations. This suggests we enter engineering development with a recognized interim technology in critical subsystems. The interim technology is replaced based on emerging technology and nearness to production.

What we require now is to adapt one or some mixture of the above approaches as policy and make it work.

> Get good counsel before you begin; and when
> you have decided, act promptly.
>
> Sallust, Catilina

Recommendations

The first two recommendations are mandatory for electronic systems R&D and their applicability to other disciplines must be studied on a case-by-case basis. The last two recommendations are supported by both my electronic systems investigations and other research on technological innovations in the more general context.

The recommendations of this study to DOD R&D managers are:

1. Establish a program of joint service evaluation of competing technologies as part of electronic system development projects.

2. Publish technology forecast for each field of 6.1 research, and task the laboratories with development of a future generation conceptual solution for major electronic systems.

3. Establish a more meaningful incentive program for government personnel and contractors that is unique to technological innovations.

4. Encourage each DOD research laboratory performing research on 6.1 fund to execute 1 to 5% of its research on problems selected from laboratories of other disciplines. This recommendation will enhance technology transfer and information exchange between laboratories.

Continuing Problems

Some problems impacting on technological innovation seem likely to persist for some time in the future, and clearly their solutions are outside the scope of this study.

First, the requirements determination process discussed in chapter I is improving, but we will continue to have a problem in

identifying requirements that are timely (early) and specific.

Second, the problem of ownership of proprietary information on innovations was discussed in chapter V (not patents, our policies deal with them very effectively). Proprietary information problems continue to receive a series of case-by-case solutions, and the problem of ownership of proprietary information is hampering technological innovations.

Epilogue

There are admittedly other approaches for dealing with technological innovations which could be postulated and considered, and others were outside the scope of this paper. The approaches, methodologies, and recommendations presented are no panacea for resolving the world's R&D problem. There is no sure solution for the immediate problem of DOD electronic systems. The approaches and recommendations presented in this study should offer a source of light in an R&D world that is dark with misunderstanding.

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APPENDIX I

INTERVIEWS

Professor Ralph I. Cole
Center of Technology and Administration
American University
Washington, D.C.
14 March 1977

Dr. Joel D. Goldhar
Office of Science Information Services
National Science Foundation
Washington, D.C.
14 March 1977

Dean Gillette
Executive Director, Systems Research Division
Bell Laboratories
Holmdel, New Jersey
21 March 1977

Dr. Walter McAfee
Scientific Advisor for Development and Engineering
US Army Electronic Command
Fort Monmouth, New Jersey
25 March 1977

T. Gordon Haines
Manager, Advance Research and Development
Pomona Division General Dynamics
Pomona, California
29 March 1977

Dean Gills
Electronic Components Technology Manager
TRW Corp
Redondo Beach, California
28 March 1977

Keith Glorfield
Space and Security Communications Division
Collin Government Telecommunications
Rockwell International
Newport Beach, California
30 March 1977

E. James Andrews
Technical Manager
Satellite Communications Systems
Rockwell International
Newport Beach, California
30 March 1977

Appendix II

Interview Questions

These questions were used as the basis for discussion in the interviews conducted during the study. In each interview, other questions and discussions surfaced; but these questions initiated the discussion and all eight were commented on in each session.

1. How important is technological innovation (including new design concepts, new system concepts, and unique ideas) for R&D on electronic systems?

2. In selecting R&D Groups or contract bidders, which is better--the group with an innovative idea or a good record?

3. What problems are common to R&D managers of DOD and their counterparts in private industry?

4. Do rewards match the risks for being innovative on DOD programs?

5. How significant is the impact of proprietary information or patent rights on innovative ideas in military R&D programs?

6. Is competition given the proper emphasis as a factor in motivating innovation?

7. How should we deal with the problem of short life spans in electronic technologies?

8. Each DOD contractor was asked to describe the company's internal decision process for IR&D funded ideas?

DISTRIBUTION

US Army Electronics Command
ATTN: DRSEL-RD-O, Dr. W. McAfee
Fort Monmouth, NJ 07703

Mr. T. Gordon Haines
Manager, Advanced Research and Development
General Dynamics Pomona Division (Dept 6, Gp 125)
1675 East Mission Boulevard
Pomona, CA 91766

Professor Ralph Cole
American University
CTA, College of Public Affairs, Hurst Hall

Dr. Joel D. Goldhar
National Science Foundation
Office of Science and Information Services
1800 G Street
Washington, DC 20550

Director, National Security Agency
ATTN: Mr. William Queen, RI
Fort George G. Meade, MD 20755

Dr. Charles H. Church
Assistant Director, Technology
Office of the Deputy Chief of Staff for
Research, Development and Acquisition
Department of the Army
Washington, DC 20310